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Work by D.E. Pritchard and his collaborators is summarized here.

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Annual Summary Report

Kristian Helmerson, Michael Joffe, Dr. Min Xiao, Ke-Xun Sun, and Professor David E. Pritchard

Office of Naval Research Contract N00014-83-K-0695

NEUTRAL ATOM TRAP

We have trapped large numbers of neutral atoms, and cooled them to millikelvin temperatures. Our next objective is to cool them to microkelvin temperatures. Dense samples of atoms cooled to microkelvin temperatures promise to open up new and exciting areas of physics. The lack of interaction of the low velocity atoms due to their reduced thermal motion, together with the possibility of indefinitely long interaction times, make samples of trapped atoms ideal for high resolution spectroscopy and for use as atomic frequency standards. High density samples of ultra-cold atoms will also open up new areas of research in studies of interatomic collisions, and collective effects, such as Bose condensation. We describe progress made in our existing magnetic trap. In addition we started a new project to develop a continuous source of slow atoms to load into future magnetic traps.

MAGNETIC TRAP FOR NEUTRAL ATOMS

Now that techniques for trapping neutral atoms are well established[1], the field of neutral atom trapping has moved from infancy to adolescence and the emphasis is now on doing experiments with the trapped atoms.

Our main current effort in neutral atom trapping is cooling of trapped atoms to low temperatures. While this remains a difficult and elusive goal (to date, micro-kelvin temperatures have only been achieved with untrapped atoms), the rewards for supercooling trapped atoms appear to be high. The long confinement times, together with the reduced thermal motion of cold atoms, could result in a new era of ultra-high resolution spectroscopy and precise frequency standards. Potentially more exciting is the possibility of combining the high densities achievable in traps and the long deBroglie wavelength of ultra-cold atoms to observe novel quantum collective phenomena.

We are currently engaged in an effort to demonstrate cyclic cooling of magnetically trapped neutral atoms[2]. This is a combined laser and radio frequency cooling scheme which should allow us to cool our atoms to microkelvin temperatures. During the past year, we have decided to try a newly designed cyclic cooling scheme which operates in a magnetic field of less than 300 gauss (we currently trap atoms at a minimum field of 1500 gauss). We have modified our superconducting magnets to allow operation of our trap at low magnetic fields. This modification will result in improved decoupling of the trapped atoms from the powerful slowing laser and may allow us to load more atoms into the trap than previously. In addition, numerous other modification have been made to the magnetic trap to optimize detection of cooled atoms and to extend the lifetime of the trapped atoms. Testing this trap is high on our agenda for 1990.

We have also performed laser fluorescence and absorption spectroscopy of magnetically trapped sodium atoms (we remain the only group in the world capable of doing both r.f. and laser spectroscopy of trapped atoms) and are currently analyzing the data. We are engaged in theoretical study of the radiative decay of densely confined atoms, where we find that there can be a substantial modification of the spontaneous decay rate of trapped atoms due to their quantum statistics. Finally, we completed a study of the Zeeman-tuned laser slowing process in the magnetic trap[3].

SLOW ATOM SOURCE

In the past year, we started to build a continuous source of slow atoms which will be simple, intense, and which will separate the slow atoms form the laser light used to slow them. This last point is crucial because it will permit the use of additional low intensity laser light to collimate, to focus, and to further cool the slow beam. Such a source may be used for loading traps, or indeed for any atomic beam experiment, without introducing the intense slowing laser light into the experiment which uses the slow atoms.

The technique is to use a continuous "zeeman slower"[4] — a spatially varying magnetic field to compensate the changing Doppler shift of the atoms in the slowing process, and a second orthogonal laser beam to deflect and extract the slowed atoms. The system has been made simple and compact, with a 25 cm long zeeman slower; atoms which start with thermal velocities greater than 600 meters/second will be ignored. Since only the low velocity portion of the Maxwell-Boltzman distribution will be slowed, a low oven temperature (about 180 centigrade) is desirable. With this low temperature, a large orifice is needed to give the requisite flux.

The major difficulty of making a continuous and intense slow atomic beam lies in the effectiveness of extraction of the atoms from the strong slowing laser beam after their slowing. We plan to do this in a region of low magnetic field using light pressure from a beam with two frequencies in order to circumvent optical pumping to hyperfine levels not excited by the laser. The configuration of the experimental arrangement is shown in the Fig. 1.

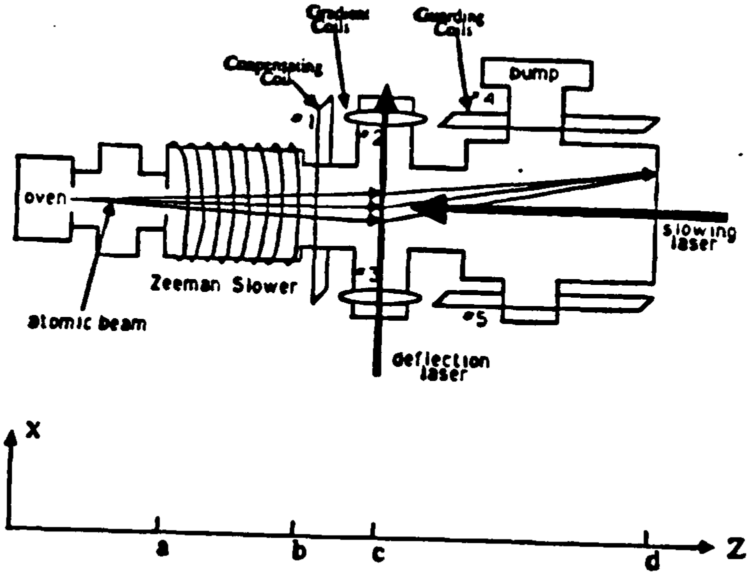

Figure 1: Schematic diagram of the slow-atom source.

Atoms with velocity smaller than 600 meters/second at position a are slowed in the zeeman slower by the slowing laser to about 150 meters/second at position b where the magnetic field is held near zero. Atoms slowed further by the intense slowing laser beam to velocities below 100 meters/second are deflected at c by the deflection laser, which is right circular polarized with a strong sideband spaced at 1.77 GHz to repump the F=1 ground state atoms. So far we have observed slowing of nearly 10^{10} atoms per second with the photodetectors mounted inside the zeeman slower.

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